Smart Connected Homes: Integrating Sensor, Occupant and BIM data for Building Performance Analysis

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Abstract

Buildings produce huge volumes of data such as BIM, sensor, occupant and building maintenance data. Data is spread across multiple disconnected systems in numerous formats, making it difficult to identify performance gaps between building design and use. Better methods for gathering and analysing data can be used to support building managers with managing building performance. The knowledge can also be fed back to designers and contractors to help close the performance gaps. We have developed a platform to integrate BIM, sensor and occupant data for providing actionable advice for building managers. A social housing organisation is acting as a use case for the platform. A methodology for developing the information needs to support data capture across disconnected systems is proposed and the challenges of bringing data-sets together to provide meaningful information to building owners and managers are presented.

INTRODUCTION

An estimated 10% (2.4 million) households in England are managed by housing associations and funded through government (Ministry of Housing, Communities & Local Government, 2017). Repair and maintenance of housing association assets falls to organisations commissioned and managed by local authorities. Publicly funded organisations such as social housing landlords come under increased pressure to reduce costs of repair and maintenance activities. The three most important areas of failure in buildings are caused through impact from weather, occupants and moisture generated from wet areas within buildings such as kitchens and bathrooms (Chong & Low, 2006). Cause of such failures provide an opportunity to investigate methodologies for understanding building performance in use against design recommendations.

Developing a platform to support repair and maintenance activities of large estate portfolio managers requires a method for understanding the organisation's information needs. This paper presents an approach for identifying: data sources for addressing those needs; and methods for capturing other data such as real-time sensor or occupant data to complete information requirements. The project is an Innovate UK funded collaborative project between Northumbria University, BIM Academy Enterprises and National Energy Foundation (NEF). A user-centred approach to understanding information requirements for managing and organising building repairs and maintenance is described. A social housing

organisation responsible for managing over 26,700 council owned properties presents a case study for this paper.

METHODOLOGY

Understanding the Information Requirements

Interviews were held with the social housing organisation's Asset Information Manager and Technical Surveyor, who deal with enquiries about and facilitate actions on, repair and maintenance issues for housing assets. From these interviews a set of use cases were developed. A follow up workshop with wider participation from the social housing organisation and local authority staff was held to evaluate and refine the use cases and understand data requirements.

Identifying Data Sources

For each use case, existing data sources were identified to better understand factors from building design and occupant activity that impacted building performance in use. Sensor platforms for measuring data such as temperature and humidity were identified and evaluated to support gaps in current data.

Site and Occupants

A newly developed site containing a mixture of 1, 2 and 3 bedroom apartments to be managed and maintained by the social housing organisation was chosen for the study. Tenants attending information events, hosted by the social housing organisation, about the site were informed of the study details. The social housing organisation gained consent for researchers to install sensors within the apartments from tenants applying for properties.

Prototype Development

A prototype sensor visualisation platform was designed to connect in-use performance data to Building Information Modelling (BIM) context data to provide actionable advice for landlords and tenants for minimising repair and maintenance activities. A mock-up graphical user interface was developed with simulated data and backend processing. A web data visualisation platform was required to visualise data to users. The platform was designed to be sensor agnostic and allow integration of multiple data types such as sensor, BIM, occupant survey or energy performance forecast data. Figure 2 demonstrates the platform system architecture.

A second workshop was held with the social housing organisation staff that manage and respond to repair and maintenance enquiries to evaluate the prototype. This workshop took a scenario based design approach to exploring how different users would use the system to perform the activities identified in the use cases developed in the first workshop. Scenario based design is a technique that describes how people will use a system to accomplish activities (Rosson, 2009). Scenarios are stories that describe a sequence of actions and events that lead to an outcome. The design phase in scenario based design involves developing activity scenarios, then information scenarios then interaction scenarios. The scenarios were designed around two approaches for notifying staff of building defects:

1. Tenant calls social housing organisation support centre to report a problem within a property.
2. Sensor platform notifies social housing organisation staff of a problem within a property.

The follow up process for each approach would be: Staff use prototype platform to identify potential problem cause. Staff either contact tenant and provide advice on how to resolve the problem, or visit the property to investigate further.

Each scenario was tested and evaluated with real-time, in-use data with workshop participants. Each scenario, based on a use case, was presented to participants. Data types for providing information for each use case was demonstrated. Methods for turning data into meaningful advice were explored. Methods such as email, text message or alerts, for notifying the social housing organisation contact centre of problems, were identified and discussed during scenario testing with workshop participants.

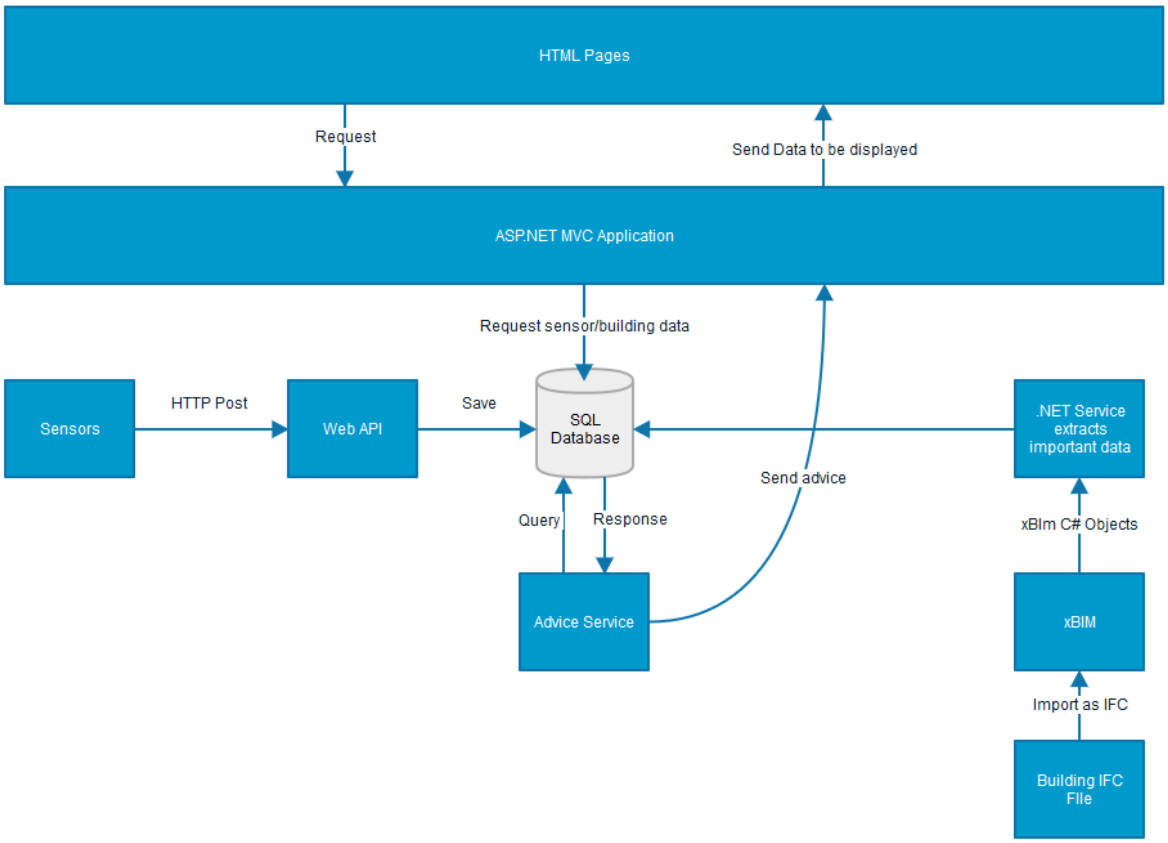

Figure 1 Platform Architecture

FINDINGS

Use Case Requirements

Fifteen use cases were identified within the first workshop: four related to energy cost savings; eight to occupancy comfort and health; and three to building performance. Cost related use cases focussed on creating cost savings for tenants. Data gathered around cost savings could support development of tenant guidance for better managing energy

consumption within homes. Comfort and health identified scenarios that affect occupants such as under heating, overheating or damp. System information could support development of tenant guidance on how best to heat and ventilate properties. Building performance related scenarios were designed to identify gaps in building performance design against use. This last category can be fed back to designers and contractors to develop guidelines for creating buildings based on real-time in-use data. Figure 2 shows the data requirements that were identified to support the use cases.

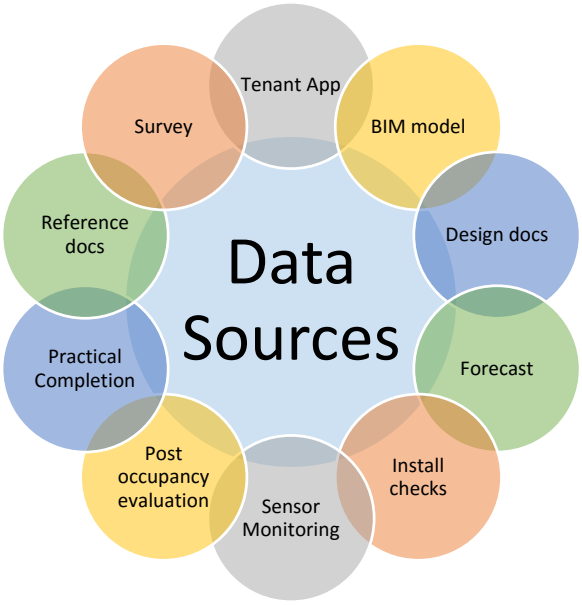

Figure 1 Use Case Data Sources

The following sensors are required to capture the gaps in current data to support the use cases:

- Room temperature (multiple locations per room)
- Humidity
- Door and window open/closed state
- Motion detection
- Ambient Light
- Gas and Electricity Usage

Electricity, boiler temperature, hot water, gas, ambient room temperature, light, humidity and motion sensors were deployed in 7 apartments within a single block.

Prototype Development

A web based prototype was developed linking real-time sensor data to a BIM model (figure 3). The spaces from within the BIM model provide the navigational structure. Selecting a space provides an overview of the space sensor data. Data can be further drilled down into by selecting a sensor to access historical data for that sensor.

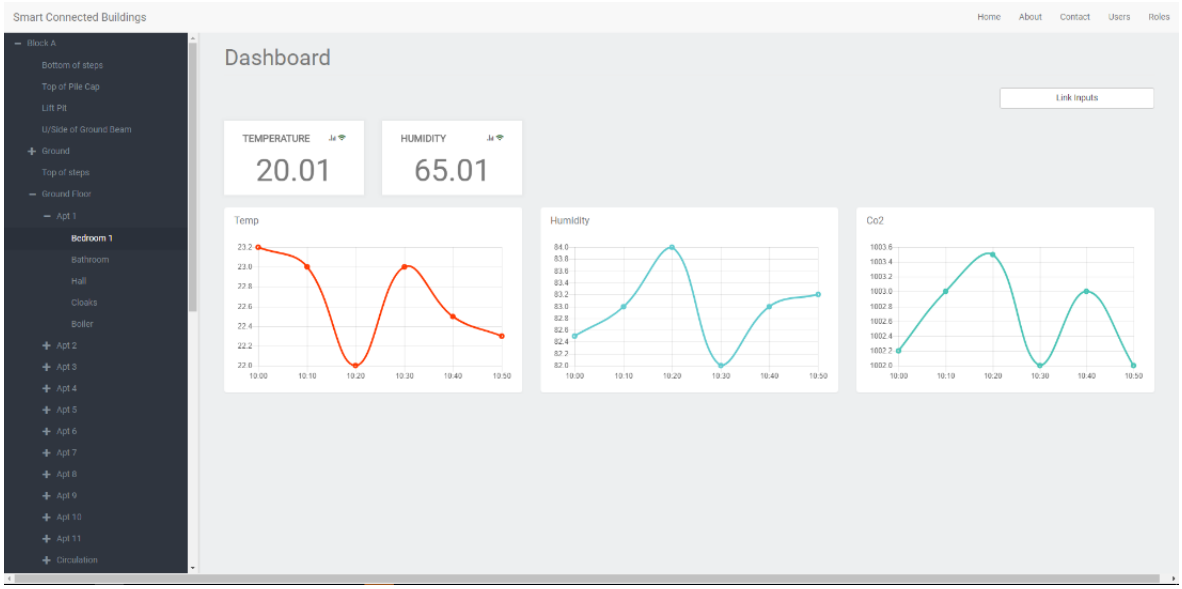

Figure 2 Sensor Visualisation Platform

A number of challenges occurred during system development. For example, the BIM model had front doors that erroneously overlapped spaces and floors, some apartments were incorrectly numbered, floors were unclearly labelled (e.g., 'top of steps'). BIM data had to be cleaned before spaces could be correctly identified and programmatically linked to sensor data. A second problem occurred around sensor deployment, a test deployment was set up and evaluated but when the deployment was installed in multiple homes the environment failed a stress test. This was resolved by installing each sensor network as an individual deployment with its own router on each floor of the apartments.

CONCLUSION

The project has successfully developed an approach for identifying sensor requirements based on a use case scenario based methodology. The project presents a number of opportunities for further developments that would benefit owners and managers of large building portfolios. Being able to measure real-time in-use post-occupancy performance data against design would provide landlords with clear guidelines to issue to building designers and contractors for new work. User satisfaction of the building can be measured against building design and performance using the platform. Having the ability to compare user satisfaction against performance allows landlords to identify problem areas and better inform tenants how to use their buildings.

Further developments to the prototype include a 3D viewer for visualising the data inputs per apartment. Having a 3D view will allow users to visualise where an apartment is within a block and assess environmental characteristics such as orientation and solar gain. Linking building fabric and infrastructure data to environmental data would enable further analysis of different data sources to assess components such as the thermal comfort and thermal dynamics of a building. Currently the system has been evaluated with a single social housing provider but further workshops are planned to evaluate the system with social housing landlords from other regions within the UK.

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